Attachment 1: Description of Emission Reduction Measure Form

Please fill out one form for each emission reduction measure. See instructions in Attachment 2.

Title: Ammonia Fuel for Irrigation Pumps (Re-Submit 9/29/07)

Type of Measure (check all that apply):

- ☐ Direct Regulation
- ☐ Market-Based Compliance
- ☒ Monetary Incentive
- ☐ Non-Monetary Incentive
- ☐ Voluntary
- ☐ Alternative Compliance Mechanism
- ☒ Other Describe: **Technology Improvement**

Responsible Agency: ARB

Sector:

- ☐ Transportation
- ☐ Electricity Generation
- ☐ Other Industrial
- ☐ Refineries
- ☒ Agriculture
- ☐ Cement
- ☐ Sequestration
- ☐ Other Describe:

2020 Baseline Emissions Assumed (MMT CO2E): 1 MMT

Percent Reduction in 2020: 100%

Cost-Effectiveness ($/metric ton CO2E) in 2020: $5/MT CO2E inititially, then decreasing to zero.

Description: It has been estimated that there are 50,000 irrigation pumps in and around the San Joaquin Valley being driven by gasoline or diesel engines. Exact figures for resulting CO2 emissions are difficult to nail down, but one report indicated that just 7000 diesel engines consumed $21 million of diesel fuel in 1998 to move water to crops. Assuming $1.50 per gallon of diesel in 1998, that would be 14 million gallons of diesel fuel consumed just for those 7000 pumps. Thus, for sake of calculations, assume that these 7000 diesel-driven pumps, which used 2000 gallons of diesel in 1998, are indicative of all types of pump engines.

Ammonia fuel (NH3) contains no carbon, and burns without any greenhouse gas emissions. Combustion products are simply nitrogen and water vapor. Gasoline engines (spark ignited) can be converted to run on 100% ammonia A diesel engine (sparkless, combustion ignition) can be converted to run on 95% ammonia plus 5% biodiesel or DME. The biodiesel and DME could be manufactured in a carbon neutral process.

Emission Reduction Calculations and Assumptions: Each gallon of gasoliine or diesel fuel that is replaced by ammonia fuel saves 20-25 pounds of CO_2 from being emitted into the atmosphere. For 50,000 pumps, each consuming 2000 gallons of gasoline or diesel, that equates to approximately a million tons of CO_2 saved annually.

Cost-Effectiveness Calculation and Assumptions: Each engine should be able to be converted to operate on ammonia or ammonia-rich blend for nominally $1000. Assuming a useful life of one of these engines to be 10 years, the annualized conversion cost would be $100. Thus, for 50,000 engines, the annualized cost would be approximately $5 million. These costs would be expected to be borne by the irrigation companies or individual farms, not by the CA government or taxpayer. These conversion costs would of course be "one-time" and go away with the next generation of irrigation pumps, which would be manufactured ammonia-ready.

There would also be a slight savings in fuel cost since ammonia fuel is approximately 2/3 the cost of gasoline or diesel on an equivalent energy basis.

Implementation Barriers and Ways to Overcome Them: The technology to operate internal combustion engines on ammonia is proven and available. There appear to be no major obstacles to implementation.

Potential Impact on Criteria and Toxic Pollutants: In addition to emitting no CO_2, combustion of NH_3 in engines produces no CO, no SO_2, and no particulates. Lab results have shown that NO_x emissions are reduced by 75% over an equivalent gasoliine engine. But the situation is actually better than that, because NH_3 itself is the active ingredient in NO_x treatment, so NO_x emissions can be effectively reduced to zero.

It is also possible to capture the clean water vapor from ammonia fuel combustion process by simple condensation. (This capability has been demonstrated for hydrogen engines and fuel cells by capturing the water for drinking purposes. The same is true with ammonia combustion.) Roughly 1 gallon of fresh water could be recovered for each gallon of ammonia fuel burned. This recovered water could be used for irrigation, or other purposes.

Name: Dr. John Holbrook
Organization: Chairman, Ammonia Fuel Network
Phone/e-mail: 509-396-2082/john.holbrook@charter.net